Off-line Character Recognition using On-line Character Writing Information

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Abstract

Recognition of variously deformed character patterns is a salient subject for off-line hand-printed character recognition. Sufficient recognition performance for practical use has not been achieved despite reports of many recognition techniques.

Our research examines effective recognition techniques for deformed characters, extending conventional recognition techniques using an on-line character writing information containing writing pressure data. This study extends conventional recognition techniques using on-line character writing information containing writing pressure information. A recognition system using simple pattern matching and HMM was made for evaluation experiments using Common Hand-printed English character patterns from the ETL6 database to determine effectiveness of the proposed extending recognition method. Character recognition performance is increased in both expansion recognition methods using on-line writing information.

1. Introduction

Realizing high character recognition performance for hand-printed off-line character pattern is a salient subject in the character recognition field. Although numerous off-line character recognition techniques have been proposed, they have not achieved enough recognition performance for practical application. Incorrect recognition results are caused by variously deformed character patterns according to copyist or writing situations. Our research presents a method for improving existing recognition techniques. Though that method, we realize a higher recognition performance for deformed character.

Proposed on-line character recognition systems demonstrate higher performance than off-line character recognition systems [1]. Higher recognition performance would be possible if on-line recognition methods were able to address drawing motion vector (stroke) information. Moreover, recognition performance could be raised using writing pressure information of on-line writer identification systems [2], and on-line character recognition systems [3].

This study proposes an improved method that applies on-line character writing information to off-line character recognition systems. For this paper, we used on-line character writing information including writing pressure information.

Moreover, this research examined a technique of extending exiting character recognition technique to raise recognition performance. Simple pattern matching methods, pattern matching based on directional features methods, Neural Network methods and Hidden Markov Model (HMM) methods are represented as typical recognition methods [4][5][6]. Hereon, we conduct a common extending method for many typical character recognition methods. Simple pattern matching character recognition and HMM character recognition methods are applied in our proposed method to evaluate the proposed common extending method using on-line character writing information.

2. On-line character writing information

On-line character writing information comprises vector patterns of pen movement at writing scene. Off-line character patterns are merely pixel patterns that include no vector information.

Although some off-line character recognition systems use some correlation of stroke information [7], all proposed off-line character recognition methods use only off-line character pattern information. However, an effective system for improving recognition performance could use some on-line writing information for off-line recognition.

Furthermore, on-line character writing information can also extract writing pressure information. Writing pressure information might also be effective for character recognition because it is reported that writing pressure information is effective for writer identification. Our study uses on-line character writing information included writing pressure.

Our research uses the on-line character writing information shown in Table 1. This database extracted uniquely as “OPPD” [8].

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Table 1. Details of On-line Writing Information

Kinds of character	Capital alphabet letters, 26
Information	Stroke vector Writing pressure 1024 level
Number of subject	30
Max image size	256pixel x 256pixcel

2.1 Off-line character recognition using stroke information

On-line character stroke information usually deals with a series of 1-dimensional (1D) vector. However, since existing off-line character recognition systems deal with 2-dimensional (2D) pixel information as an input, 1D vectors are translated into 2D pixel information. Concretely, in our research, feature extraction is performed from on-line stroke information; the features are used as 2D gray-scale feature image for recognition inputs.

Stroke information is vector information that represents sampling points of every stroke. Changing points of vector direction are detected as a feature image. The huge directional changing area might be a deformed stroke at writing time.

Furthermore, since the relation of each stroke might be important feature of character patterns, intersection area of two or more strokes are also detected as a feature image.

Although these feature images are detected from thinning image, it is inappropriate to treat off-line thick images equally; feature images are expanded. After processing character data of 30 subjects are aggregated, "stroke changing feature areas" are extracted. Figure 1 shows “stroke changing feature areas” detected from 30 characters of the capital roman (English) alphabet.

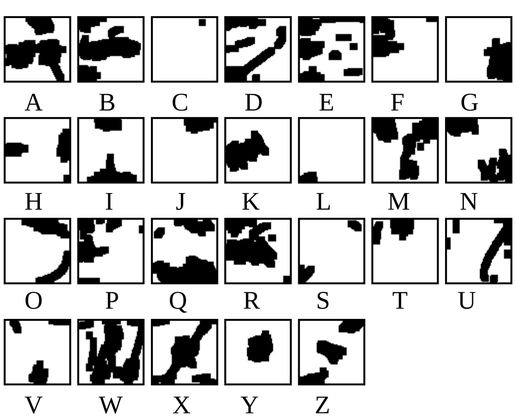

Figure 1. Stroke changing feature area

2.2 Off-line character recognition using writing pressure information

Writing pressure is extracted by 1024 levels according to the on-line character database. However, subjects’ writing pressure values differ greatly even when writing identical character. Writing pressure data reflect a subject individual’s idiosyncrasies and situational information.

Therefore, in our research, we detected the amount of writing pressure changes among pixels; we decided to use the value rectified to 256 levels as a feature. Thus, writing pressure information was used not as an individual feature, but as a character feature.

After accumulating calculation results of 30 subjects, the “writing pressure changing feature area” shown in Figure 2 is extracted from capital alphabet letters. In Figure 2 white pixels express no change in writing pressure; black reflects maximum change in writing pressure.

After this section, on-line character writing information included writing pressure denotes “on-line data”

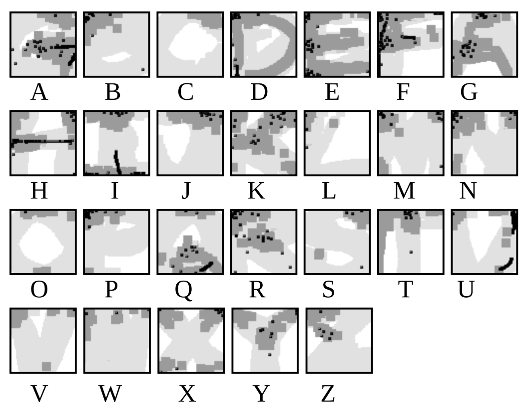

Figure 2. Writing pressure changing feature area

3. Extension of the off-line recognition method using on-line data

Simple pattern matching character recognition and HMM character recognition methods are extended using feature areas shown in Figure 1 and Figure 2,. Both recognition methods are selected as representative recognition methods. Each extension technique is explained below.

3.1 Extension of the simple pattern matching method using on-line data

Simple pattern matching method is the most fundamental technique for off-line character recognition. The most fundamental pattern matching recognition method is expanded for on-line data and evaluated effects to examine the simple effect of using on-line data for off-line character recognition.

This study extracted two kinds of feature images shown in Figure 1 and Figure 2. They were chosen for use as an image weighting pattern on preprocessing stage. After these two weighting filters are used independently, these two resultant images are aggregated. Resultant weighted standard images and a weighted strange image are used to perform pattern matching. Then, recognition result is calculated.

Specifically, weighting using stroke information and weighting using writing pressure information function under the following rules.

- If a concentration value of character patterns on a stroke changing feature area exceeds a threshold value, the concentration value around the pixel is recalculated by averaging neighboring pixels.
- If a concentration value of character patterns on a writing pressure feature area exceeds a threshold value, the concentration value of the pixel is enlarged for fixed magnification.

These rules result from the following conditions. Character strokes are often deformed for off-line character patterns around an area where stroke change is large. A deformed area of a character is inferred to be calculated from smoothed image regions, not from each independent pixel value.

Moreover, character strokes often represent some characteristic features of each character around an area where writing pressure change is large. Pixels having characteristic features are transformed so as to have effective calculation value.

Furthermore, if there is a pixel of strange character image and the same coordinate pixel having 0 (white) values on weighted standard character image, pattern matching calculation is carried out on some penalties. The penalty is calculated by following modified similarity formula.

Let class n ($n=1, 2, 3\dots N$) represent the kind of character to recognize,

$T(x,y)$ be a pixel value of test image,

$S_n(x,y)$ be a pixel value of class n standard image,

α be a weighting fixed value,

penalty value $\gamma_n(x,y)$ is define as

$$\gamma_n(x,y)=\begin{cases}0 & (if \quad S_n(x,y)=0)\\ \alpha T(x,y) & (if \quad S_n(x,y)\neq 0)\end{cases}.$$

At these conditions, modified similarity calculation P_n is given as

$$P_n = 1-\frac{\sum\left|T(x,y)-S_n(x,y)\right|-\sum\gamma_n(x,y)}{\left\|T(x,y)\right\|\times\left\|S(x,y)\right\|}.$$

3.2 Extension of 1D HMM method using on-line data

Some character recognition methods using Hidden Markov Model (HMM) are reported having high recognition performances. The conventional 1D HMM character recognition method is also extended to incorporate on-line data to evaluate the proposed recognition method using on-line data. The extension is performed similarly to the extension method for simple pattern matching without using modified similarity calculation. Thus, in our research, both learning and test sample are translated using on-line data and inputted to HMM.

4. Evaluation experiment

Extended character recognition methods are constructed. Then, an evaluation experiment is conducted using the database.

4.1 Common Hand-printed character database

Our experiments used Latin hand-printed character samples (A-Z) from the ETL6 database [9]. Binalization, noise deletion and size normalization are done in the preprocessing stage. Samples including large noise are excluded in this step. The average number of samples in each class is about 1,300.

Four samples out of each class are used as the standard image for simple pattern matching method’s evaluation. A pattern matching based on directional features method is constructed for a comparative experiment. For pattern matching based on directional features method’s evaluation, 200 samples from each class are selected and aggregated into 20 images.

For HMM method’s evaluation, 600 samples from each class are used as the learning set; the rest are used as the test set for each class.

For all evaluation, the size of the number of the test set is up to 18,435.

4.2 Effects of the pattern matching method using on-line data

Table 2 shows experimental results of simple pattern matching method, the proposed method using on-line data, and pattern matching based on the directional features method (for comparison). Table 2 shows that our proposed method offers better recognition performance than the simple pattern matching method. Moreover, our proposed method has very close recognition performance to pattern matching based on the directional features method using only 1/20 the calculation time for matching. That is, our proposed method using on-line data is effective for the pattern matching method.

Table 2. Recognition result of pattern matching method using on-line data

	Cumulative recognition rate		
	1	2	3
Simple patter matching	84.5%	91.6%	94.2%
Proposed method	88.2%	93.5%	96.5%
Pattern matching based on the directional features	97.5%	94.1%	96.2%

4.3 Effects of the HMM method using on-line data

Table 3 shows the experimental results of simple 1D HMM method, proposed 1D HMM using on-line data method and MD-HMM method (for comparison. Refer from [6]). Table 3 shows that our proposed method offers better recognition performance than 1D HMM method and MD-HMM method on top-rank recognition results; it is close to the performance for the top three cumulative recognition results. That is, our proposed method using on-line data could be effective for the character recognition method using HMM.

Table 3. Recognition result of 1D HMM using on-line data

	Cumulative recognition rate		
	1	2	3
1D HMM	93.6%	95.9%	96.4%
Proposed 1D HMM	96.5%	98.5%	99.0%
MD-HMM	95.0%	98.3%	99.3%

4.4 Relations of proposed method and the number of learning sample

For HMM recognition method, we inferred that it has similarly effects to increasing the number of learning samples using on-line data. The evaluation experiment was conducted changing the number of learning samples.

Figure 3 shows the top rank recognition rate of simple 1D HMM method and proposed 1D HMM method using on-line data. Figure 4 shows the top three recognition rate of simple 1D HMM method and proposed 1D HMM method using on-line data.

Figure 3 and Figure 4 results show that higher recognition performances are realized using smaller number of learning samples. Thus our proposed method has the effect of controlling the number of learning samples.

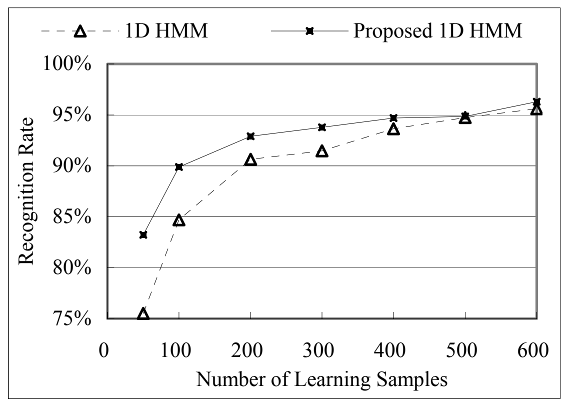

Figure 3. Top rank recognition rate of proposed 1D HMM (learning sample set)

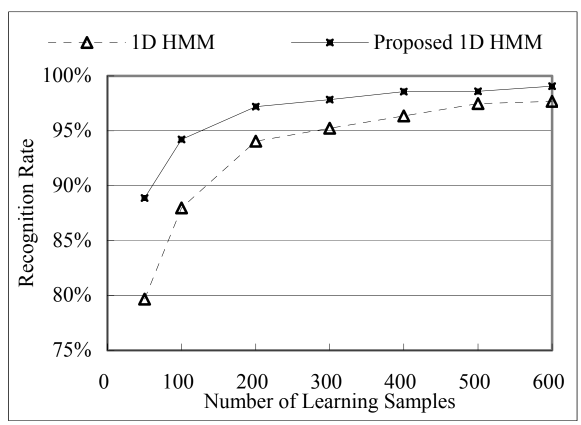

Figure 4. Top 3 cumulative recognition rate of proposed 1D HMM (learning sample set)

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5. Conclusion

This study proposes a recognition method using on-line writing information including writing pressure information. Our proposed method uses on-line information as an image-weighting filter in a preprocessing stage.

Our evaluation experiments confirm that our proposed methods provide higher recognition performance than both simple pattern matching recognition method and HMM recognition method. Our proposed methods have slightly higher performance than conventional effective recognition method, pattern matching based on directional features, and MD-HMM recognition methods. Thus, our proposed method is very effective to realize a higher recognition performance.

Moreover, for pattern matching recognition method, our proposed method realizes very close recognition performance to pattern matching based on directional features method using only 1/20 of the calculation time for matching.

For HMM recognition method, our proposed method has an effect of controlling the number of study samples. This also indicates that our proposed method is a method for capable of conducting efficient learning.

As explained above, we believe our proposed method is an effective method to realize high recognition performance in practical application.

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